SOME ADVANTAGES OF FIELD-WORK ON SURFACE WATER SUPPLIES

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There are several ways of procuring a water-supply. The simplest is by catching the rain as it runs from the roofs of houses and storing it in cisterns. Where provision has been made for passing the first portion of the rain, saving only that which falls later, and when the cistern has been carefully built, this is a satisfactory method. But the amount that can be obtained in this manner is small, and serves, at the most, to supply only two or three houses. Another source of supply is the underground water which is derived from springs, wells, and filter-galleries. Carefully operated works of this class usually afford a water of excellent quality and one which is very satisfactory to the consumers. Unfortunately, however, it, too, is limited in quantity, and besides, as larger demands are made on it, tends to deteriorate, becoming constantly harder and at the last carrying bacteria in high numbers. By far the greater part of our cities are supplied with surface water which is taken from rivers,—with or without filtration,—from natural lakes, or from artificially constructed storage reservoirs. It is the purpose of this paper to point out the necessity of carefully conducted field-work in those places whose supplies are obtained from the two last sources.

As the rain falls to earth, it washes the dust, the spores of microscopic organisms and the bacteria from the air, and absorbs from it various gases. But these impurities are trifling as compared to those it acquires after it reaches the ground. The character of a water is determined by the watershed from which it is collected.

To make what follows perfectly clear, let us imagine a watershed which comprises all the features commonly found in the localities on which water-supplies are built. It has an area of about one hundred square miles and a somewhat diversified topography. There are a few high hills, one of which is crowned by a large town, which is sewered, and whose sewage disposal works are outside the watershed. Through the town runs a brook which flows onto English filters at the shore of a lake which forms part of the system of water supply. The effluent from these filters runs directly into the lake. All of the hills slope abruptly to the flat land at their base. A river with its numerous tributaries courses through the middle of the watershed. On one of these streams whose drainage area is wild, wooded, gravelly land, and which has its rise in dense cedar swamps, a storage reservoir is built. A second and larger tributary flows through a cultivated district whose soil is a loam mixed with considerable clay. Here and there are farm houses with the accompanying live stock, and some distance away is a hospital with its own water supply and English filters for sewage disposal. This stream has been dammed at three points, and each of the storage reservoirs thus formed has its own tributaries which for the most part are fed by springs. All of the brooks enter the reservoirs at the head, and on some of them dams have been built to form mill-ponds. These are now abandoned. The soil has been stripped from the bottoms of all the storage reservoirs, which vary from fifteen to fifty feet in depth, and have a capacity of two billion gallons. They are constructed so that water can be drawn from the surface, mid-depth and bottom. The lake is somewhat isolated from the storage basins; it has a capacity of three billion gallons, and the bottom has never been cleaned. The mains are built so that water can be drawn from all the supplies at once, or any source may be used independently of the others. No houses are allowed on the shores of these ponds, and the whole district is under rigid sanitary supervision.

Let us first consider the chain of reservoirs which are built on the stream flowing through the inhabited area. The first rain that falls after a long dry spell will be soaked up by the earth, but as the storm continues the capacity of the ground to do this becomes exhausted, and the excess of water must flow away over the surface. Not in clear rivulets, however, but in very dirty ones, for the continual beating and pelting of the rain loosens the clayey soil so that it is easily dislodged and carried away by the water toward the reservoirs. Moreover, we have said that the valley of the stream is cultivated; this necessitates manuring, and if there are market gardens, heavy manuring, which means that some and possibly much night-soil is used. Thus a chance is afforded for disease germs to be washed into the reservoirs, and in any case many bacteria and nitrogen in the form of nitrates will be gathered from this source.

So these little rivulets flow on with their ever increasing burden of mud and putrescible matter and deposit it in the feeders of the reservoirs. Of course the gross polluting centers, such as barnyards, privies, etc., have been kept from draining directly into the supply. It is only the small waste incident to life, to which man and beast alike contribute, that is carried into the storage basins. The swollen feeders are now adding bacteria to the reservoir and mud to make them turbid. This is an objectionable state of affairs, for from the head of the reservoirs the roily water, high in bacteria, moves onward till it is delivered to the consumers or passes out of circulation. Its progress through the reservoirs must be carefully watched. It is not enough to wait till samples collected at the intake announce its appearance there. The superintendent not only ought to know the character of a water he is using at a particular time, but he should be kept informed as to whether it is likely to improve or deteriorate in quality.

Turbidity is a deterioration, and is justly complained of by the consumers; not that it is injurious to the health, but for aesthetic reasons. It makes the water unsightly, and imparts an earthy flavor to it. The degree of turbidity depends upon the amount of clay in suspension. The sand particles soon settle out, but the clay, which is very finely comminuted, does so very, very slowly. If a little clay is brought to the supplies by a short rain, it may sink to the bottom before it reaches the mains, unless the reservoirs are kept stirred up by the wind. On the other hand, a severe storm will bring much clay, which will gradually pass through the reservoirs to the intake.

It is evident, that careful records of the clearness of the water should be kept. There are several ways of estimating turbidity. The oldest is by determining the weight of suspended matter in a given weight of water. This method is being abandoned because of its inaccuracy. A small amount of sand would raise the weight of suspended matter very considerably without a corresponding gain of turbidity, while a large addition of clay would cause a marked increase of turbidity without materially increasing the weight of matter in suspension.

Nowadays, the commonest ways of measuring turbidity are by means of the Silica Standards,* Diaphanometer,† and the Platinum Wire.‡ Each has its advantages, and that must be selected for use which is best adapted for the work in hand. Still another method was formerly employed on the Metropolitan Water Works; a disc,§ five inches in diameter and painted like a surveyor's target, is lowered into the water, and the greatest depth at which the divisions can be distinguished is recorded.

In reservoirs several factors work toward reducing the bacteria. They tend to sink to the bottom, and, besides, the water is not as favorable a medium for them to grow in as is the land from which they have been washed; further, the sunlight is inimical to them. So altogether they fare badly after they reach the supplies, and the chance of their reaching the intake are somewhat less than that of the clay.

It is well after a severe storm to make a thorough examination of the supplies. So we go in a boat from the foot to the head of the reservoirs, taking turbidity readings and bacteria samples at frequent intervals. The bacterial examinations are mainly quantitative, supplemented by tests for coli reactions. It must be so, as a search for disease germs among the host of other bacteria would be as futile as the search for the needle in the haymow. This work serves to let us know the condition of the reservoirs soon after the rain. A few days later the trip should be repeated and, by comparing the results obtained then with the former ones, we can tell whether the chances favor increased bacteria and turbidity at the intake or whether they will disappear without occasioning disturbance. If one of the reservoirs is in an unsettled condition from these causes we shut it off for the time being, and draw from one which appears to be normal. In this way complaints from consumers can be avoided, and a feeling of security established in the community which would have been impossible without the field-work.

We have taken up the two main factors which menace the

* Technology Quarterly, Vol. XII, No. 4, p. 283.
† Technology Quarterly, Vol. XII, No. 2, p. 145.
‡ Hazen, Filtration of Public Water Supplies, 3d edition, p. 118.
Whipple, The Microscopy of Drinking Water, p. 75.

supply in the inhabited district, but there remains to be considered the abandoned mill-ponds and the hospital. The mill-ponds will be spoken of later. Let us turn our attention to the hospital. It is situated on high ground at some distance from the chain of reservoirs, but the effluent from its disposal works must finally find its way into the supply. For this reason it is imperative that the English filters at all times do their work perfectly. It will not do to trust entirely to the hospital authorities in this matter. They will undoubtedly be honest in their intention to run the filter beds properly, but the best of employes grow lax at times, and accidents will happen so that he who is responsible for the purity of the water supply should be able to say that at such and such a time the beds were doing thus, and so. Much tact is necessary, in a case of this kind, where a third person must concern himself with another's business, but if all approach the matter in the right spirit there need be no friction.

The field-work on the storage reservoir in the wild land takes on a different nature. As the soil is gravelly there will be little additional turbidity after rains, and as it is uninhabited no great increase of bacteria that may be objectionable. But this reservoir, in a small way, but in a serious one, is liable to contamination. We have indicated that it is wooded; its chief feeder rises in a cedar swamp, and its shores are covered with deciduous trees. This being so, it will be a resort for picnic parties, and for any one who wishes a day's outing. They should not cause trouble, but unclean people will be among them, and they will not fail to arrange matters so that some foecal matter will find its way into the supply. The sick, and not the well, will offend oftenest. The danger is a real one, and the only relief is to have the shores so thoroughly policed that sinning will be difficult. It will not do to rely for protection on bacterial examinations. As has been said before, it is next to impossible to distinguish the disease germs among the shoal of other bacteria. We must keep them out of the supply, and not rely on hunting them down after they are once in.

It may not be amiss to speak here of the danger of allowing skating, fishing, and camping on bodies of water which are used for drinking by man. The evil is the same as in the case of the picnickers, and so these sports should be prohibited. A public water-supply is not a plaything, nor a playground; it is an extremely sensitive and expensive plant, built to administer to certain definite needs of the entire people, and should not be sacrificed to the pleasures of a few. Of the same kind of nuisance is the inexcusable and unnecessary custom of manuring the sides of reservoirs to get thick grassy slopes. The practice is a filthy one and dangerous besides, for in the majority of cases the origin of the manure is unknown, and it is not at all impossible that it contains disease germs. If it does the wind and rain will surely not leave them on the shores. When enrichment is desired it would seem perfectly feasible to use some of the cheap chemical fertilizers.

But to return to the reservoir once more. Color is the other point to be considered in regard to this source. We have said that the feeders rise in swamps; in flowing through them they will acquire a deep red color. This will be more noticeable some times than at others. When the water flows rapidly through the swamps, it will be much lighter colored than when the flow is sluggish, and time enough has elapsed for it to leach out the coloring matter from the roots and peat. In the late spring it will be particularly dark, for the water which comes out then has remained backed up in the swamps all winter, and besides the leaves which were shed by other trees than the evergreens the autumn before have disintegrated and their coloring matter is added to that from other sources.

When the influents reach the head of the reservoir, their course depends on their temperature and that of the reservoir itself. If the temperature of the feeders is such as to make their density less than that of the reservoir, the dark influent, unless disturbed by winds, will flow over the surface of the reservoir to the intake, arriving there almost as dark as when it entered at the head. If the density of the influent is greater than the reservoir water, it will flow along the bottom; if they are of the same density or high winds prevail, their waters will commingle. Sunlight bleaches the water somewhat so that the reservoir is likely to be lightest colored at its foot. At best, the water is too dark to be used by itself without disquietude on the part of the consumers; so when distributed it must be mixed, in such quantities as not to cause comment, with the light colored water of the supply. This is very nice work, and it makes it necessary for the color of the water to be accurately determined.

Not only must color samples be taken, but careful record of the temperature of the reservoir throughout its greatest depth must be kept, together with that of the influent streams. At the outlet color readings must be made on samples from the surface, mid-depth and bottom, in order that water may be drawn at that point where the color is the lightest. Also the color of the influents must be determined besides that of samples taken at various points intermediate between the foot and head of the reservoir. This is done to trace the progress of the water through the basin. All this work occasions frequent visits to the supply, but the time is profitably spent, for no change in a water is so quickly noted by the citizens as that in color, and superintendents value highly the information which enables them to anticipate criticism from this cause.

Turning our attention next to the lake, we find as its most striking feature the proximity of the town on the high hill. The town is a constant threat to the purity of the lake. To be sure, the sewage is carried outside of the watershed, and the brook, which takes almost all of the surface drainage which escapes the sewers, is filtered. But the town with its busy life is there, and if an accident should happen to the sewerage which should let the sewage unobserved into the lake or some similar misfortune should occur, trouble would surely ensue. The best the water works managers can do is to watch the filters carefully, and to be constantly on the alert for escaping sewage from the sewerage system. Those places where it passes near brooks which empty into the lake should be especially guarded. Bacteria samples should often be taken from the brooks, and frequent trips for inspection should be made along their banks.

To watch the filters is a comparatively easy matter. In the first place the plant should be in the hands of a competent person. Then bacteria samples should be taken from the effluents at regular intervals, and at any time the operator of the station may see fit to suggest. Whenever bacteria samples are taken from the effluents a bacteria sample and a sample for microscopical examination should be taken from the applied water. As the lake is fed by springs, and as the only important influent is filtered there will be little trouble from turbidity and color.

We have now taken up the salient features of each source of supply which necessitates peculiar field-work on their watersheds. One characteristic which is common to all remains to be discussed. I refer to the growth of microscopic organisms and the tastes and odors caused thereby. When we first began to strip our storage reservoirs, we found that we had removed the organic matter so thoroughly that large growths did not exist, and we hoped this condition would be permanent. Experience has proved otherwise. The organisms have gradually established themselves in reservoirs which were built in the most painstaking manner. Many causes contribute to this result. Perhaps the three most prominent ones are the increase of population on the watershed, the slow accumulation in the reservoirs or organic matter from the feeders, and the bringing in of microscopic forms by these same brooks. So we must acknowledge the growths to be common to all reservoirs. Not in equal degree, however, for we ordinarily expect them to be smaller, and to occur less frequently in the basins where the cleansing has been most perfect.

It is the duty of the water works biologist to know the organisms that cause trouble, to study the conditions under which they occur, and to so draw from the supplies at his command that the water served to the community shall be palatable and wholesome. He can never do these things satisfactorily unless he has an intimate personal knowledge of the system, and this can only be gained by much field-work.

It will not do to rely entirely on the analyses made in the laboratory of samples collected by another. They give no idea of the distribution of a growth, and at times are very misleading as to its size. The collector may be attracted by little specks in the water and, knowing that they are of interest to the analyst, try to get as many as possible into the bottle. Or he may have been warned against doing this, and so, almost unconsciously, try to keep the sample clear. Again, he may be very much hurried, and take the sample without noticing the condition of the water at all, it being merely a matter of luck whether it is a representative one or not. Indeed, analyses of samples taken in this manner simply show what the collector dipped up. A carefully trained collector would ordinarily do effective work, but the results obtained on his samples must be checked by work in the field if a comprehensive idea of the growths and the conditions which make for and against their development is to be obtained. The field-work must not be conducted in a haphazard way, but the general principles which influence plankton growths must be kept in mind.

As the name implies, the plankton is made up of floating growths, and many of them float near the surface of the water, while others live at some depth beneath it. But all are influenced by currents and winds. There is a steady current from the influent to the foot of the reservoir, so that there will be a tendency for all forms to be swept toward it. Then the wind will blow the growths hither and thither over the pond, now toward one shore, now toward another. Not only does the wind waft them from place to place, but distributes them also in the vertical through which it acts. So those forms which usually grow in the upper five feet and those which float conspicuously on the surface will be mixed with those which develop at a depth.

When the wind subsides they again take their normal position in this vertical. It is easy to see how all this may influence the samples. In the first place, organisms may be blown towards or entirely away from the usual collecting points. So easy is it to be deceived by this occurrence that it is not a bad plan to have the direction of the wind noted on the sample tag. If the samples are taken soon after a high wind they will give an entirely false idea of the vertical distribution of the organisms. Moreover, a small growth may be carried from its place, and collect about the intake. A bottle received from the collector at this time will create uneasiness which will be dispelled by a visit to the works where the true size of the growth is revealed, together with the fact that it will be dissipated again by the wind, leaving the water as good as ever.

Matters do not always work out as satisfactorily as this. These microscopic organisms commonly develop in bays and nooks where there is a shallow flowage, and in places where the cleansing of the reservoir has not been thorough. It happens at times that they are blown from these places out into the reservoir, and there increase enormously, causing the water to become very offensive to taste and smell. If the biologist finds a growth of this kind on his hands his procedure will be determined by the results of his field-work. If they show that the growth is confined to the surface, water may still be drawn from the mid-depth and bottom. This state of affairs many times exists in the case of growths of cyanophyceae and of some infusoria. But if it has been learned that the whole reservoir, from surface to bottom, from foot to head, is infested there is nothing to do but shut off the supply, and wait until the vigor of the growth is abated before using it again. Now this is a vital point. By putting the works in the care of a competent biologist, and constructing them so that water may be drawn from the surface, mid-depth and bottom, as occasion may require, it is perfectly feasible to deliver at all times good tasting water to the users. Even in the cases where there is only one source of supply much may be done in this direction, and where there are many sources to supplement each other the water should always be good. Our municipalities have not yet learned this lesson, but they must be made to as a matter of decency and economy. The microscopic organisms, besides developing in the shallows and bays of a reservoir, may be brought into it by the influent streams. Ordinarily they do not carry many organisms, and those that they do carry are quite harmless forms, such as Anthophysa, a few chlorophytes, and diatoms. But if the streams expand to broad quiet pools in some places, or if they rise in swamps which contain ponds, they may bring from thence many organisms which will work harm in the reservoirs below. These little swamp ponds and pools in the streams are ideal places for certain infusoria and cyanophyceae to breed, and they may reach a large development there, being retained in these localities as long as the weather is dry, and the streams are low. A heavy rain, however, washes them into the reservoirs where they are likely to grow, and do much injury. I believe many storage reservoirs which have been stripped at great expense have been spoiled by neglecting to eliminate the ponds from swamps and the pockets from the streams.

It is in this connection that we should consider the effect of the abandoned mill-ponds on some of the feeders of the chain of reservoirs. In summer time the microscopic organisms are bound to develop abundantly in them, and a long rain will make them overflow, and deliver their noxious growths into the stream; once there, the journey to the reservoirs is a short one. These ponds are always a great cause of worriment to the biologist. Samples should be taken from them often enough to determine their predominant organisms, and the grade of their water surface should be read from time to time, that they may not overflow unexpectedly, and so start a considerable growth, which may remain for a time at the head of the reservoir, unobserved by the biologist.

The seasons of overturns of the ponds are periods of great activity in the field. As this phenomenon is dependent on the temperature of the water many temperature readings ought to be made before and after it occurs. The overturn is succeeded by a rapid multiplication of diatoms and other forms, so that many samples have to be taken for microscopical examination. It is not till the material brought up from the bottom has been oxidized, and has settled out, and the microscopic organisms have in consequence somewhat decreased that there can be any let up in this work.

Some water works are built so that one reservoir can be filled from another, and not infrequently it is necessary to do this. Here is another chance for field-work, for the empty basin should never be filled with water of questionable quality. When such a work is to be undertaken, the biologist should invariably visit the works in person and assure himself that there is no marked turbidity, that the color is low, and that there are few organisms. It would be the height of folly, for instance, to fill an empty reservoir in mid-summer when so many organisms of all classes are present in the water. With the advent of cold weather many forms die so that the actual number of organisms is less, but of vastly more importance is the fact that many of the spores, which in warm weather are somewhat generally distributed in the water, sink to the bottom, and there remain till the spring overturn brings them to the surface and sunlight again. The significance of this is that we have a choice; we may fill our reservoirs with water which is comparatively free from organisms, and is likely to remain so, or we may fill them with water holding a multitude of forms which in time will die, leaving seed-like bodies, which will inevitably germinate as soon as conditions favorable to their development recur. In the light of these facts, it seems as though we ought always to act cautiously and wisely in the matter of running the water from one place to another in the system. But at times an apparent necessity tempts us to take chances which prudence would forbid our accepting. If we yield to these promptings, it should be with a full realization of the fact that it is easy to give the microscopic organisms a foothold in our reservoirs, but that it is not so certain that we are ever entirely rid of them again.

Elsewhere, I have spoken of nitrates in a manner which indicates that they are deleterious to a supply. It is only right to qualify this, for they are not injurious to health, but they are a detriment in that they serve as a food for the algae. Now the nitrates of a watershed increase with population; consequently, when it becomes very dense we may expect much trouble from these alone. In ground water supplies we ordinarily find high nitrates, but they are not harmful so long as the sunlight is excluded. Under its influence, however, the chlorophyllous plants produce extremely abundantly. Indeed so marked is this tendency that reservoirs for waters of this class are usually covered.

Many examples of the efficiency of field-work might be quoted to emphasize its value. But as we have treated the subject in a general way it does not seem fitting to do this. It will be sufficient to cite one case where its results were much appreciated by those for whom it was undertaken.

The town of A bought water from the Metropolitan Water Board; at the same time it used some of its own water, and this mixed supply was delivered to the consumers. The A supply was filtered water taken from filter-galleries near the shore of a lake, and this was mixed with the surface water supplied by the Board. The mixing did not take place in an open reservoir but in the mains. For a time all went well, but suddenly the town of A complained that the Metropolitan water was unfit to drink. I at once investigated the matter. Samples were taken from the reservoir which the Metropolitan Water Board used to supply A, from the A taps, from the A filter-galleries, and from the lake near which the filter-galleries were built. The analyses showed that the water from the Metropolitan reservoir was good, and that from the A taps was bad. It followed that the trouble must be with the water supplied by A itself. There were two organisms, Crenothrix and Coelosphaerium, in the A taps water which were not in the Metropolitan water. The water from the filter-galleries contained Crenothrix but not Coelosphaerium. The water from the lake contained great quantities of the latter, and as it was this which was causing the trouble it was important to discover how it got into the supply. The superintendent bethought himself of a pipe which was formerly used to let water direct from the lake to the town mains. A visit to this solved the mystery; the valve which closed the pipe was leaking badly. When it was replaced the trouble stopped.